Reprinted from THE LANCET, *Aug.* 4, 1900.

ON THE LIMITATION OF PHYSICAL METHODS IN THE INVESTIGATION OF THE PHYSIOLOGICAL AND PSYCHICAL PHENOMENA OF SIGHT.

BY F. W. EDRIDGE-GREEN, M.D. DURH., F.R.C.S. ENG.

IN a paper published in THE LANCET of May 26th (p. 1511) I showed how difficult it was to correctly ascertain the colour perception of any person if we ignored colour names. In this paper I wish to show that in investigating physiological, psychical, and pathological phenomena we must employ methods which are suited to the case in hand and not those which are so admirably adapted to the study of the physical phenomena themselves. We talk of light and heat as if they were two different things, but the difference exists in us, not in the physical stimuli giving rise to the sensation. The physical stimulus is that force which, acting upon the body, gives rise to a sensation. For instance, the force which, acting upon the eye, gives rise to the sensation of light when falling upon the back of the hand gives rise to the sensation of heat, and may when falling upon the back of the head covered by hair give rise to no sensation whatever. Again, different physical stimuli may cause the same sensation as a blow on the eye causing the sensation of light. Many years ago a well-known physicist who was discussing my views on colour-

vision remarked : " I explain the Young-Helmholtz theory in the following way to show how by the admixture of three constituents we can form all colours. If we take whisky, sugar, and water we can by mixing them in varying proportions obtain mixtures of an unlimited number, each differing from the other." But he was entirely overlooking the man who had to taste the whisky. The mixtures which could be made are innumerable, but the number of distinct mixtures which could be recognised by any person are very limited. In the case of a man who has been accustomed to take a glass of whisky every day for 20 years it is improbable that the constituents were twice alike, viewed from a physical standpoint, but to him they have appeared exactly alike. If my view be correct, that colour is a point of difference perceived by a perceptive centre in the brain, a method which aims at ascertaining the colour perception of an individual by measuring the apparent luminosity of the colours he perceives is as likely to achieve the desired result as it would be if applied to ascertain any other idea of the mind.

I will now give an example showing how inefficient these physical methods are to elucidate the phenomena of colour perception. I was the first to point out that intermediate between normal and dichromic colour vision there are those whose vision is pentachromic, tetrachromic, and trichromic. Let us consider those whom I have designated as having trichromic vision, because it has been asserted by so many physicists that normal colour vision is trichromic. A person whose colour vision is trichromic may see a spectrum of the same length as the normal-sighted, but he sees only three colours—red, green, and violet. He sees no orange, yellow, or blue in the spectrum. In fact, many have remarked to me that red-green would be a far better name than yellow and violet-green than blue, and they frequently used these terms. Yellow and orange do not appear to them as definite colours, but as transition colours between red and green. Tested in every possible way it is found that their vision is trichromic ; they never mistake red and green for each other and laugh at the possibility of making this mistake, but are always in difficulty over orange, yellow, and blue. In a classification of colours the same mistakes are made : some yellows are put with red, others with green ; some blues are put with violet, others with green. Yet examined by physical methods these persons may appear normal-sighted, and I may mention that several colour-blind persons of this class have been

passed by a physicist as normal-sighted. It is obvious that a method of colour-matching which has for its theory that normal vision is trichromic will show that these persons are normal-sighted. They usually pass the Holmgren test with ease. They are, however, most dangerous persons at sea, as they are never certain about a yellow light and continually confuse it with red and green. When I was appointed by the Board of Trade to advise that body on the subject of colour-blindness one of the first cases that was referred to me was of this kind. The man could always distingnish between red and green, but was continually in doubt about yellow. It must be perfectly obvious to the reader that a man who cannot see any yellow in the spectrum and who thinks that red-green would be a better name for yellow cannot have normal colour vision. To me, the yellow of the spectrnm or a yellow flower appears an absolutely distinct colour, in which it is not possible to distinguish either red or green. Blue and orange are also absolutely distinct colours to me.

I will now give a bare outline of my views on the perception of colour[1] as it will make the points which I wish to discuss more intelligible. I believe that light acting upon the retina liberates the visual purple from the rods and a photograph is formed, the cones and optic nerve-fibres conveying the impression to the brain. Kühne stated that the visual purple cannot be essential to vision as it is absent from the cones and only cones are to be found in the fovea centralis, the region of most distinct vision. This fact, however, furnished me with a ready means of testing the truth of my theory. I have made numerous experiments which prove that unless light falls as well on a portion of the retina containing rods it may fall on the fovea centralis without producing any sensation. The reader may convince himself of this by a very simple experiment. Fasten a piece of black velvet about three feet square on a door, and in the centre of the velvet pnt a pin so that the head is directed towards the observer. If the source of light be behind the observer the pin will be brightly illnminated, but on looking at it and keeping the eyes quite still the pin will disappear, the visnal substance diffused into the fovea centralis being used up and not renewed. When viewed by indirect vision it is

[1] Colour Blindness and Colour Perception, International Scientific Series.

impossible to make it disappear in this way. Single isolated stars when not too bright may be made to disappear in a similar manner. In a dim light and with one eye shut a large portion, and sometimes the whole, of the field of vision will become totally black from the centre outwards. In this experiment the whole of the visual substance is used up and not re-secreted. It is easy to suppose that the visual substance becomes liquefied and diffused into the fovea centralis. This theory is supported by some hundreds of experiments, for instance that the area of greatest luminosity of the retina is at the point where the rods are most abundant, &c. This view occurred to me when I had not one-twentieth part of the evidence in favour of it which I have now. But during the last 10 years I have collected evidence that proves not only that there is a visual substance but that that substance is purple—namely, the complementary of pure green. It is probably only seen as purple when in excess. Under certain conditions a purple after-image can be obtained after white light and every spectral colour. If we rub one of our eyes in a dark room a purple light appears. It will be noticed that the visual purple is in every way suitable for the visual substance. It gives a continuous spectrum. It is easy to suppose that light might liberate the visual substance just as heat melts an ointment, but we have evidence that the cones themselves help. Engelmann and Van Genderen Stort have shown that there is a shortening of the inner segments of the cones under light, but this cannot convey any light sensation, as the same action has been found to take place when the light falls on another part of the body. This action would cause a vacuum. In my experiments, in which I have caused lights to apparently disappear, I find that the experiment succeeds best if only one eye be used and the greatest care be taken that no light falls on the face or any other part of the body. I believe that shortening of the spectrum is due to some defect in this visual substance as there is light as well as colour loss, which is not the case with colour-blindness due to defective psycho-physical perception. The visual substance being decomposed by light sets up by chemical, mechanical, electrical, or some other physical action, impulses which are conveyed to the brain through the cones and optic nerve-fibres, the cones being the terminations of the perceptive fibres in the retina. The whole impression being brought to the centre of memory, different portions of the impression—colour, form, size, luminosity,

&c.—are conveyed to the mind through definite perceptive centres. In the case of colour, this perceptive centre is only able to distinguish six definite points of difference (colours) in the spectrum which really presents millions. We, therefore, for the normal-sighted have a hexachromic theory of colour-vision which is independent of light and shade. A hexachromic theory will obviously explain all that can be explained by a trichromic theory. It also agrees with the fact that both blue and violet have been demonstrated to be primary. I may say that I totally disagree with the theory that normal colour vision is trichromic, and am of opinion that the curves and equations which have been constructed to prove that vision is trichromic are mathematically incorrect. I have raised this point as an objection to the Young-Helmholtz theory in a paper recently read before the Royal Society. Equal stimulation of the three sets of fibres is supposed to cause the sensation of white light. Red and green when mixed make yellow. Violet and green when mixed make blue. But yellow and blue when mixed make white, which makes one portion of green too many, thus:— R + G = Y, and G + V = B, but Y + B = white, therefore, R + G + G + V should equal white, but R + G + V = white.

The degrees and varieties of colour-blindness are perfectly explained by the theory of psycho-physical perception. Assuming that the perceptive centre is smaller fewer points of difference are seen. The phenomena of contrasts are explained on the view that colour being a point of difference this becomes more marked on comparison. If we contrast a yellow with a greenish-yellow the yellow inclines to orange and the greenish-yellow to yellow-green. This could not be explained by assuming that the colours differ by the addition of the complementary to each, as the complementary of yellow is blue and this mixed with yellow would make white instead of orange-yellow.

In addition to the points which I have already raised the following appear to me as serious objections against the ordinary physical methods of ascertaining the colour perception of an individual.

Absorption of light by the media of the eye.—It is obvious that the media of the eye vary slightly in colour in different persons. This produces a variation of the colour curve in each case without in any way affecting the real colour perception of an individual. For instance, a normal-sighted

person's vision is still hexachromic when he looks through a pale yellow glass.

Hyperæsthesia to certain colours.—Another source of error in matching colours with white light is that persons differ as to their sensibility to all colours or to certain of them just as they differ in their physiological actions in other parts of the body. One person can read in a very feeble light but is dazzled by a light which to another person is quite comfortable. A person of this kind matches a red with a grey which is much darker than that chosen by another person, though both may have equally good colour perception. Again, men vary as to their sensibility to certain colours; one is more affected by red, another by green, and another by yellow. We can also have temporary hyperæsthesia, an exaggerated example of which is found in photophobia.

Idea as to comparative luminosity.—In matching colours with white light or with each other much depends upon the observer's idea of the colour. If I make a match of red and grey with the idea that red is a very bright colour I shall make a match with a much lighter grey than I should if I had the idea that red was a very dark colour.

If the theory as to a photo-chemical substance be admitted then the action of light on the substance may produce an excessive reaction with one person and very little with another; the apparent luminosity would be much greater in the first case. The secretion of fresh photo-chemical substance may be quicker in one person than in another. We know that the visual purple may be bleached by monochromatic as well as by mixed light. If we suppose the visual substance of the eye to be decomposed in the same manner it would be possible to understand that we might get similar curves of luminosity by different colours though the visual impulses sent to the brain might in each case be different. If there be, and all recent research points to the fact that there are, different centres in the brain for the perception of luminosity and colour, it is obvious that ascertaining the luminosity of a colour will not give us any information concerning that colour because the two are absolutely and totally distinct. In order to make my meaning clearer I will make a comparison with the organ of hearing. The perception of pitch is in every respect analogous to the perception of colour and

yet no one would dream of endeavouring to obtain any information concerning tbe pitcb of a note by observations on tbe intensity witb which it is struck.

In conclusion, I will point out tbat we must always be careful in examining a person by physical metbods that we do not obtain results wbicb are only pbysical, cbemical, and electrical phenomena. When tbe pbenomena are psycbical they can not be measured by tbe balancc and the rule but must be gained by direct evidence from tbe mind itself.

Hendon

PRINTED AT THE LANCET OFFICE, 423, STRAND, W.C.